Coastal Heritage

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Communities Under Water

Lessons Learned from Extreme Floods

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Milton Green compares the October 2015 and October 2016 flood heights in his yard in North Charleston's Pepperhill subdivision. The October 2015 flooding was higher, but Hurricane Matthew still did major damage to his house.

PHOTO/GRACE BEAHM

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RISING CONCERN. *The October 2015 flood inundated many coastal communities, including Aiken Street on the Charleston peninsula, and taught many lessons.* PHOTO/GRACE BEAHM

Communities Under Water

Lessons Learned from Extreme Floods

by Joey Holleman

From narrow neighborhood ditches to major rivers, nearly every waterway in wide swaths of South Carolina swelled to extreme levels during and after a record-breaking rainfall in early October 2015. "It's never flooded like that around here" seemed like the new state motto. The tendency might have been to view the resulting flood and its $2 billion in damages as a once-in-a-lifetime disaster and not let it remarkably change the way we work, live, play, and plan.

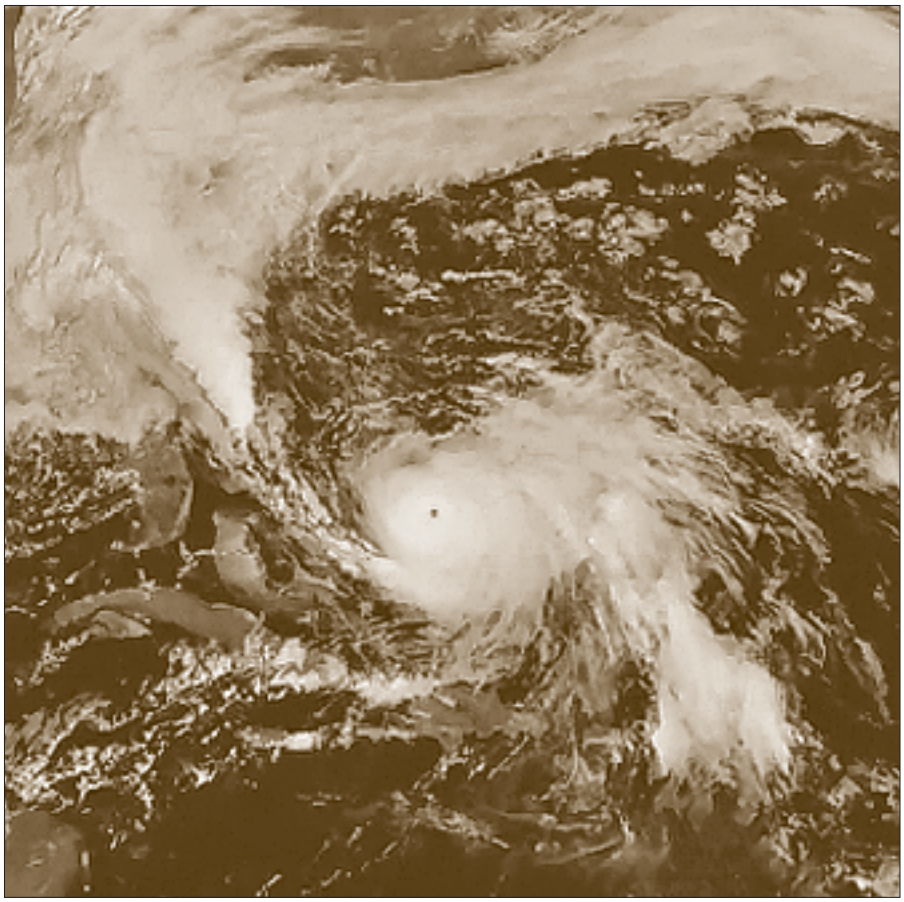
Then Hurricane Matthew churned up the coast in October 2016, dumping slightly less rainfall but enough to cause another major flooding event in coastal South Carolina. The new motto this time could have been: "Not again!" In the extreme northeast corner of the state, Matthew flooding was even worse than in October 2015, thus driving home two points.

First, these types of extraordinary meteorological and hydrological events are growing more common. The amount of precipitation in the most powerful storms in the Southeast increased by 27 percent from 1958 through 2012, according to a report from the National Science and Technology Council. The phenomena, coined "rain bombs," make scientific sense: Global temperatures have been on the rise, and warmer air holds more water vapor than cooler air. Those skeptical of statistics and studies need only pay attention to news reports. Before the end of October 2015, the South Carolina flood had faded in national memory behind two deadly floods a week apart in Texas. Additional record-breaking deluges hit Arkansas, West Virginia, Maryland, and Louisiana before Matthew gave South Carolina another thorough drenching.

And secondly, 500-year floods, a misunderstood term based on statistics, don't happen just once every five centuries. The laws of probability don't work that way. Instead, the term refers to a 0.2 percent chance of one of those events occurring during *any* year. While South Carolina didn't get 500-year floods in back-to-back years in exactly the same location, Matthew pushed the Little Pee Dee River to 500-year levels at Galivants Ferry in 2016, which is about 50 miles from where the Black River hit 500-year levels in Kingstree in 2015.

Both of those points stress the need for all of us to learn from our flooding experiences. Using that knowledge to prepare people, homes, and infrastructure to better handle the next major flood builds community resilience.

"It amazes me that people haven't thought more about resilience," says Gerald Galloway, a University of Maryland engineering professor whose research focuses on flood resilience and mitigation. Galloway made that comment at a February 2016 symposium



FIREHOSE EFFECT. *Hurricane Joaquin remained off the South Carolina coast in October 2015, but it set up in just the right spot to funnel moisture from a land-based low pressure system, which drenched South Carolina with over two feet of rain in some areas.*
PHOTO/NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

organized by the Charleston Resilience Network (CRN), a relatively new group of public and private stakeholders, including the S.C. Sea Grant Consortium. The CRN was formed to help communities prepare for and deal with events such as the October 2015 floods.

According to the Federal Emergency Management Agency (FEMA), flooding accounts for 85 percent of all disaster declarations in the United States. Flooding caused $260 billion in damages from 1980 through 2013. Improved community resilience won't stop flooding, but it could reduce the impact.

"Resilience is where it's at," Galloway says. "What are we doing to make us better the next time around? We can't afford $6 billion in flood losses in this country every year."

OCTOBER 2015: ATMOSPHERIC FLOOD RECIPE

South Carolina was bone dry in early August 2015, with crops dying in fields and many waterways running at 10 percent of their normal flow. Farmers and gardeners welcomed a couple of quenching rains in August and September, but the state's streams still were very low. Then in early October, while most people were paying attention to strengthening Hurricane Joaquin in the Atlantic, a separate low-pressure system stalled over southern Georgia.

The land-based low plopped down in an ideal location for its counter-clockwise rotation to pull moist air up from the tropics. When that saturated air lifted over the low's stalled frontal boundary, rain poured down on South Carolina. The first round of rain had little to do with Joaquin, but moisture in the outer bands of the hurricane likely fed into later rounds, says Ron Morales, warning coordination meteorologist with the National Weather Service (NWS) in Charleston.

NWS forecast models recognized the flood potential early, warning on October 1 that Charleston should expect more than 10 inches of rain over the next four days. "Everyone was worried about Joaquin," Morales says. "We were trying to get people to stop looking at Joaquin and look at this rain forecast."

Heavy rain started in Charleston on the afternoon of October 1. Then it stopped late on October 2. Hope Mizzell, state climatologist with the S.C. Department of Natural Resources (SCDNR), heard from skeptics when the first blast of rain ended. She begged them not to take the forecast lightly.

"With each forecast, it became more clear somewhere was going to get it," Mizzell says. "You didn't know precisely where the maximum amount would fall, but you knew there was a high likelihood it would happen somewhere. After it slowed down, I told people who were contacting me, 'Do not even think this is over!' "

It wasn't. The atmospheric fire hose opened full throttle over Charleston during late afternoon October 3, pushing into the central part of the state and the northern coast overnight. By the time skies cleared on October 5, one-third of the area's average annual precipitation had been crammed into four days in coastal and inland communities from Charleston north to Myrtle Beach. One site in Mount Pleasant registered 26.88 inches. Four-day totals included 24.75 inches in Williamsburg County, 23.74 inches in Horry County, and 22.02 inches in Berkeley County.

Flood records were set on the Black River at Kingstree, Black Creek near Quinby in Florence County, and on Gills Creek, Smith Branch, and Pen Branch in Columbia. It's impossible to accurately determine

the peak at Gills Creek. The deluge washed away the gauge.

The force of flowing water buckled roads and tested the strength of dams. The official tallies from a state infrastructure damage report: 541 roads and 221 bridges closed; 52 state-regulated dams and another 191 smaller dams damaged. Most of the dams simply overtopped and suffered erosion, but several in the Gills Creek watershed failed, cascading massive pulses of water through suburban Columbia neighborhoods that never had flooded before.

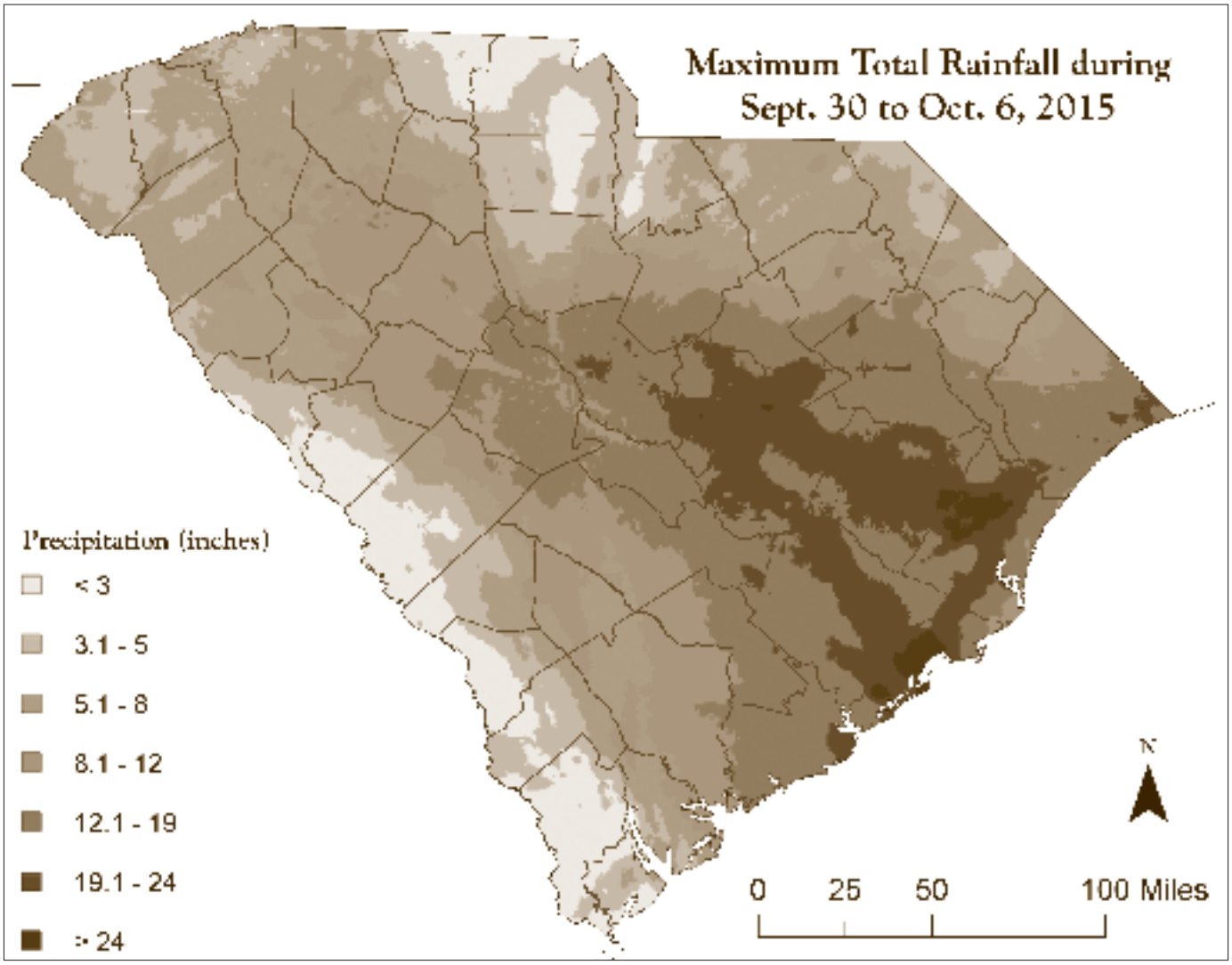
In the lowcountry, high water forced the closure of sections of U.S. 17 both north and south of Charleston. Main Road, the major connection from U.S. 17 to Johns Island and Kiawah Island, was shut down for days. Further inland, portions of I-95 also had to be closed.

The rising water didn't play favorites, enveloping high-end mansions and mobile home parks. State officials say 33,100 homes had more than a foot of water in them at some point during the resultant flooding, which continued for two weeks as water moved downstream. Thousands of people had to be plucked from homes by rescuers in boats. Officially, 19 deaths were linked to the 2015 flood, with three of those in coastal counties. The majority of deaths occurred when people drove into flooded roadways. The overriding lesson: Don't drive into water—turn around, don't drown.

Many people whose homes were impacted by the rising waters now say they fanatically check weather forecasts. Mizzell hopes that is another lesson learned from October 2015: Pay attention to forecasts and don't assume you are safe.

"It had been so long since we had experienced a flood," Mizzell says. "You knew everybody's response would be, 'It won't be a problem in my neighborhood.' People who have lived in their home 20 years and it's never flooded think they're not in a flood zone. Twenty years is a very small climatological footprint. Next time, people will recognize that we are vulnerable."

When the "next time" came just a year later, people did pay attention. State officials estimated 350,000 fled the coast after Governor Nikki Haley



MAP PREPARED BY A. SASSARD USING DATA CREATED BY METSTATE, INC. FOR THE S.C. STATE CLIMATE OFFICE

ordered an evacuation ahead of Hurricane Matthew. Even with powerful winds and storm surge, Hurricane Matthew caused five deaths compared to 19 during the 2015 flooding.

FLOOD HITS ON A PERSONAL LEVEL

On the night of October 3, 2015, Milton Green, like many in South Carolina, was entranced as the Clemson-Notre Dame football game came down to a final drive. He also was aware of dire rainfall predictions. Throughout the game, he got up from his recliner during commercial breaks to check on water rising slowly across his backyard in North Charleston's Pepperhill subdivision. The frantic last few minutes of the game stole his attention away from his flood checks. When the Clemson Tigers finally closed out the victory, he says, "I put down the footrest on my recliner, and my feet went 'squish'." The carpet in his low-lying living room was soaked.

Green hustled his wife and granddaughter out of the higher section of the house and drove out of the neighborhood as quickly as possible. Good thing he did. "When I came back the next day, the water was so deep I had to reach down into the water to put the key into the front-door lock," he says.

Green moved into the house in 1989, and he says it never had flooded before. But water from neighboring wetlands had been slowly creeping higher in his yard after each heavy rain for about a decade. He speculates the change is related to construction during that period of the nearby Palmetto Commerce Parkway.

Hydrology studies required for the parkway indicated the road should create little additional runoff into the wetlands behind Pepperhill. The study estimated the parkway would add 36.2 acres of impervious surface—or hard surface that doesn't soak up rainfall—to the 4,400-acre drainage area. The ditch system leading to the neighboring Bluehouse Swamp area was estimated to easily handle 4,600 cubic feet per second (cfs) of runoff in a 100-year rain event. The new road was estimated to add 100 cfs, and the additional flow enters the system downstream from Pepperhill.

Of course, the parkway's road surface is far from the only new construction in the area. Businesses have popped up along the parkway, and hundreds of homes have been built to the west, or upstream, of Pepperhill in the past 20 years. Regardless of the source, something is causing ditches around Pepperhill to back up with water quicker than they did several years ago, even during summer thunderstorms. North Charleston officials want a more comprehensive study of the wetlands, ditches, and creeks that flow beside Pepperhill and the nearby Northwoods Estates subdivisions. They have applied for a FEMA mitigation grant to pay for the study.

Pepperhill homeowners were more than a little frustrated that they flooded again during Hurricane Matthew before the watershed study was done. Green, who evacuated before Matthew, returned to find 10-15 inches of water in his house. He had spent $60,000 getting it back in good shape after October 2015, much of that from a Small Business Administration loan. Now, he needs to start all over with the stripping of floors and sheetrock to prevent mold problems. The only mild solace: He learned one important lesson in October 2015 and bought flood insurance between the two events, so most of the repair costs won't come out of his pocket this time around.

Green would gladly take a buyout offer for his house. "The only thing they can do is get us out of here now," he says, "because the next flood is going to do the same thing."

After the 2015 floods, North Charleston requested FEMA flood recovery money that could be used to buy and demolish up to nine homes that have flooded multiple times on New Ryder Road in Northwoods Estates. Funds and approval from FEMA hadn't come through by October 2016, and those homes flooded again. The homes that flooded in Pepperhill in 2015 weren't eligible for that round of buyouts because

CHANGING LANDSCAPE. *North Charleston city officials have pledged to do a hydrology study to determine what's causing backups, and how to prevent them, in Pepperhill and other nearby subdivisions.*
PHOTO/GRACE BEAHM

they weren't considered repetitive loss properties. They might be eligible if FEMA designates buyout funds for Matthew flood victims. In 2015, there were 1,508 homes statewide considered repetitive loss properties, up from 1,131 in 1998 before Hurricane Floyd, according to FEMA. The number most likely will go up due to Hurricane Matthew.

In addition to seeking funds for a watershed study for the Bluehouse Swamp area, North Charleston officials have discussed strengthening building codes. The city already requires a one-foot freeboard, or bottom floors one foot above 100-year flood level, in new construction. The city of Conway enacted a two-foot freeboard after Hurricane Floyd flooding in 1999. A recent federal mandate requires all buildings constructed with federal funds have at least a two-foot freeboard, and all critical infrastructure must have a three-foot freeboard. Those types of flood resilience steps could be an important effect of the 2015 and 2016 flooding, experts say.

SOLUTIONS CAN BE COMPLEX, COSTLY

Charleston has more experience with flooding than most communities in South Carolina. A big chunk of the peninsula's infrastructure has been built on top of filled-in tidal creeks, which routinely are the first places to flood during extreme tides or heavy rain. Charleston city leaders have put resilience in the forefront. The city came up with a comprehensive sea-level rise strategy, with nearly 80 recommended initiatives based on sea level rising 1.5 to 2.5 feet in 50 years.

City leaders in recent years have approved two property tax increases and a stormwater utility fee. The city has spent, or plans to spend, $235 million on stormwater improvement projects from 1990-2020.

The work involves digging shafts down more than 100 feet, carving horizontal tunnels, and installing pumps to move water away from problem areas. One section, on Calhoun Street from East Bay to Meeting streets, was completed in 2001. Another in the Market Street area was mostly finished by October 2015. Flooding in those areas in October 2015 was minimal, but storm surge during Hurricane Matthew backed up several feet deep in the city market.

SWOLLEN WATERWAY. *The Black River hit record flood heights in October 2015, turning farm buildings in Williamsburg County into unnatural islands.*
PHOTO/MARIA COX LAMM/S.C. DEPARTMENT OF NATURAL RESOURCES

The worst flooding in Charleston's city limits in 2015 wasn't on the peninsula; it was in suburban neighborhoods west of the Ashley River. "When it floods there, it floods from thunderstorms," says Laura Cabiness, director of the city's Department of Public Service. "Those thunderstorms can happen two or three times a year, and they're very tricky to predict. With a hurricane, we have time to evacuate people. With these thunderstorms, we don't have much time. So now, in addition to watching sea-level rise and storm surge, we're watching these rainfall events."

Charleston was aware of the potential for flooding in the suburbs. The first of the city's stormwater improvement projects in the 1990s was in the Ardmore area of West Ashley. Also, homes in sections of the Shadowmoss Plantation subdivision have flooded multiple times in recent decades. A complex of townhomes flooded for the first time in 1986. Then new homes constructed in a section along Bees Ferry Road flooded multiple times in the 1990s.

This prompted the city and Charleston County to fund a project that installed three new 72-inch culverts through a nearby railroad berm in 1997. When those homes flooded again, the city knew something was going on in the Church Creek basin that drains Shadowmoss and surrounding communities.

"The homes that flooded weren't in the FEMA flood zone," Cabiness says. "We did a mapping study, and the FEMA flood maps were just downright wrong when those areas were developed."

It appeared, Cabiness says, the flood maps were influenced more by storm surge than by rainfall. The potential blocking effect of the railroad berm on the eastern side of the development was seen as a positive against storm surge coming up from the coast, but it also served as an impediment for

BUILDING RESILIENCE. ***New homes in the Fox Hollow subdivision on James Island didn't flood in 2015 or 2016, in part because the developer used low-impact design techniques that reduced hard surfaces, raised houses, and detained stormwater in a natural swale.***
PHOTO/GRACE BEAHM

heavy rainfall flowing out of the neighborhood toward the coast. After a city mapping project in 2002, additional stormwater storage areas were added to the basin, a diversion project was built to intercept runoff on the east side of Shawdowmoss, and a culvert was built to move more water from the townhome complex to a nearby pond. Those improvements were designed to handle 20 percent more stormwater.

That didn't prevent flooding in the neighborhood in 2015 or 2016. The townhomes and several other homes in the subdivision filled with several feet of water in both cases. Those are among the homes Charleston has proposed to buy, with homeowners' permission, and demolish with federal mitigation funds.

The area around Shadowmoss continues to be developed at a rapid pace, but builders in those neighborhoods now face strict runoff regulations. In most of the state, stormwater systems in new developments must be designed to handle—through outflow or absorption—the runoff of 10-year or 25-year floods. After its 2002 mapping project, Charleston required all new development in the Church Creek basin be designed to handle runoff of a 100-year flood. "We have to look at our options today, make smart choices, and look ahead with the best science in mind," Cabiness says.

Joshua Robinson is on the leading edge of such a smart-building trend. His firm, Robinson Design Engineers, created a low-impact concept for the Fox Hollow subdivision on James Island, near Charleston. "With low-impact design, you try to mimic the natural hydrology," Robinson says. "You slow down the movement of water with vegetation so it can infiltrate."

The 2.65-acre Fox Hollow development features nine homes built with raised crawl spaces on a slight berm on one side of a narrow, winding road, with a stormwater detention swale on the other side. There are no pipes to direct rainfall. Water rose out of the swale and into the road, but the homes didn't flood in October 2015 or during Hurricane Matthew.

BUILDING BETTER FLOOD MAPS

Accurate flood mapping is another important component of resilience, and the science behind it keeps getting better. In August 2016, the National Oceanic and Atmospheric Administration (NOAA) launched the National Water Model, a new forecasting tool designed to offer more detailed and timely flood forecasts. Powerful NOAA computers crunch data from more than 8,000 U.S. Geological Survey (USGS) gauges nationally, creating simulations for 2.7 million locations.

"This model expands our forecast locations 700 times and generates several additional water variables, such as soil moisture, runoff, stream velocity, and other parameters to produce a more comprehensive picture of water behavior across the country," says Thomas Graziano, director of NOAA's Office of Water Prediction.

The model might have helped emergency personnel during the October 2015 floods. After Hurricane Matthew, it factored in rainfall and soil conditions in the Black River watershed around Kingstree and correctly forecast the river would peak at about half the volume of the 2015 flood.

In South Carolina, College of Charleston professor Norman Levine is creating a mapping tool to forecast flooding at a more precise level. Funded by a NOAA grant obtained through the S.C. Sea Grant Consortium and the Charleston Resilience Network, Levine's mapping tool uses LiDAR laser-measured elevations accurate to within +/– 5 centimeters (about 2 inches) to show which portions of Charleston County will flood during certain conditions. The maps factor in rainfall amounts, tidal stages, and stormwater infrastructure, including locations of storm drains and size of pipes. Eventually, they will

incorporate soil type, number of trees, locations of wetlands, and percent of impervious surface, Levine says.

A prototype of the mapping tool proved incredibly accurate during an October 2015 test run. It estimated extreme flooding that coincided with a tidal event, called a "King Tide," would reach the edge of a fountain at the intersection of Morris and Jasper streets in Charleston. It also predicted the street would flood but not the alley between houses across from the fountain. Photos taken during the King Tide almost identically match the mapping tool's blocky one-meter estimates.

The team working with Levine is updating those maps and expanding them to include the entire county under the NOAA grant. Then Elizabeth Fly, coastal climate extension specialist with the Consortium, will lead an effort to help community leaders, infrastructure managers, and the general public understand how the maps can be utilized.

The maps can be tools to guide emergency officials on where to place barriers to stop drivers from entering high water, and where to position rescue boats before a flood. They could inform the renovation of buildings and improvements to infrastructure on the nearly built-out Charleston peninsula. The maps can also help position neighborhoods to be better prepared for what may come next.

HURRICANE FLOYD TAUGHT LESSONS IN 1999

The most recent severe widespread flooding in South Carolina that occurred before October 2015 was during Hurricane Floyd, which hit Horry County harder than any other. Floyd damaged more than 1,000 homes in Horry County, and $8.6 million in federal and state mitigation funds allowed the county and the city of Conway to buy out about 100 properties for demolition, according to FEMA.

Randy Webster, Horry County's emergency management director, hopes others in the state will learn from the Floyd fallout in his county. Buyouts work best if the homes purchased can be clustered together. In two communities on the banks of the Waccamaw River, only a few homeowners took the post-Floyd buyout. Many homes in those neighborhoods flooded in October 2015 and again after Hurricane Matthew in 2016.

"We have a lot of little donut-hole FEMA properties," Webster says. "We don't have enough all together to create a wetland to help with flooding. We learned from that, and from this point forward, we will target areas to create wetlands."

During the 2015 and 2016 events, Horry County emergency officials at least knew what areas were likely to flood as rivers began to swell with rain and runoff. They had the Floyd experience as well as accurate readings from upstream river gauges. Georgetown and Williamsburg counties didn't have recent flooding experience or as much river data available. USGS, which manages river-level monitoring systems nationwide, has no gauges in Georgetown County, and few in Williamsburg.

"We had to make river-level forecasts using old-school methods," says Sam Hodge, Georgetown County's emergency management director. "We used sign posts, even broken down tractors in yards. You see how high the water is on the tires in the morning, then check later in the day. You could see the wave as it moved across the county, but it took us a while to figure out the rise and fall."

Upstream of Georgetown County during the 2015 flood, a gauge established in 1973 on the Black River in Kingstree hit 22.65 feet, nearly three feet higher than the highest previous flood. Georgetown County residents knew the water was coming, they just didn't have a good handle on when and where to evacuate or when they could safely return to their homes.

Hodge praised USGS, which rushed out 16 teams to measure high-water marks and place rapid-

RECURRING DILEMMA. *Rain combined with high tide often creates nuisance floods like this one in 2014 in Charleston and lead to conversations about resilience.*
PHOTO/GRACE BEAHM

deployment gauges in local rivers in October 2015. John Shelton, supervisory hydrologist with the USGS in South Carolina, acknowledged the 2015 flood brought to light several gaps in the system. His agency would like to have more gauges, but it relies on state or local agencies and private businesses to pick up the cost of installing and maintaining them.

High-tech gauges, which beam information to satellites, cost $15,000-$18,000 up-front and about $15,000 per year to operate. There are 164 gauges in the state providing real-time data. The number has increased steadily in recent years, but gauge density is lacking in South Carolina compared to neighboring states, Shelton says. Legislation introduced during the 2016 session to appropriate state funds for 70-100 new gauges failed to gain approval.

The USGS and coastal emergency officials made the most of their lessons from 2015. As forecasts indicated Hurricane Matthew was going to bring heavy rain to coastal South Carolina, local officials knew to ask for rapid-deployment gauges before the storm's arrival. And as Matthew's impacts transitioned from coastal hurricane surge to inland flooding, some of the gauges were moved to inland communities, Shelton says. The state had fewer gauges available—nine in 2016 versus 13 in 2015—because it couldn't borrow gauges from storm-threatened Georgia this time. But earlier and more strategic deployment allowed those fewer gauges to provide more timely data to emergency officials.

NOAA's new National Water Model offers another alternative for places like northwestern Georgetown County with few permanent USGS gauges. In addition, a new tool in South Carolina could help by making it easy to find water quantity and water quality data generated by USGS, U.S. Forest Service, S.C. Department of Natural Resources, S.C. Department of Health and Environmental Control, and university researchers. Prompted by difficulty locating that data during the October 2015 flood, the S.C. Sea Grant Consortium pulled together those entities to create the S.C. Coastal Water Monitoring Network and design an online portal to make the sharing of their information easier.

WELCOME RELIEF. *Williamsburg County homeowner Martha McFadden prays with Eight Days of Hope volunteer Johnny Wildes after her home was evaluated for repair work.*
PHOTO/GRACE BEAHM

LESSONS CAN BE UPBEAT

While most of the lessons learned from the October 2015 flooding were practical, one was especially heartening: People really want to help. Volunteer groups flocked to hard-hit communities. The challenge was how to take advantage of their offers. "We know our local volunteer agencies, but when volunteers were coming from everywhere, it was kind of overwhelming," says Hodge, Georgetown County's emergency management director.

Georgetown and Williamsburg county officials found residents were more comfortable dealing with local groups, so they channeled monetary donations through the local United Way, says Stanley Pasley, county supervisor in Williamsburg County. The United Way ended up hiring a temporary coordinator to handle the volunteers and donations.

A year after the 2015 flooding, nearly 1,200 volunteers from the charity Eight Days of Hope flocked to the Kingstree-Andrews area for a blitz recovery effort to repair homes. Three weeks before the October blitz, volunteers Johnny Wildes and Garrett Ganas of Waycross, Georgia, were on the advance team assessing what work needed to be done. They found homes with gaping holes in the roofs, walls speckled with mold, or entire walls torn out to remove mold.

Compared to those families, Martha McFadden was lucky. The 2015 floodwater from a nearby creek reached the edge of the crawl space on the back of her modest home in rural Williamsburg County, but she didn't have to evacuate. A year later, she had a few moldy spots on the ceiling and on a bathroom wall, a collapsed roof

HELPING HANDS. *Johnny Wildes and Garrett Ganas, volunteers with Eight Days of Hope, measure a Williamsburg County home's roof in preparation of the national charity's blitz effort to repair lingering damage from the October 2015 flood.*
PHOTO/GRACE BEAHM

over the garage, and a weathered tarp on the roof over a bedroom. "I sit in my chair when it rains and pray the water doesn't come through," McFadden says. "I get scared every time I hear about a storm."

Wildes and Ganas checked out the damage to McFadden's house and included it on the Eight Days of Hope project list. McFadden thanked them for their willingness to help, and, after a closing prayer, there were hugs all around.

Unfortunately, the volunteers ended up spending the first few days clearing 140 trees Hurricane Matthew had tossed onto buildings and roads. They still managed to repair 70 homes. Fortunately, the Black River in Kingstree and Andrews didn't rise as high after Hurricane Matthew. But the 2016 floods brought the same type of destruction to communities 50-60 miles away on the Little Pee Dee and Lumber rivers.

"The biggest takeaway for me and for the county is no one could have imagined the extreme devastation that took place in such a short period of time," Pasley says of the 2015 flooding. "A lot of our folks who experienced the storm in the most dire manner, they're experiencing a new way of life, a new norm. It changed life permanently."

CAN MOMENTUM BE MAINTAINED?

But will the October 2015 floods and Hurricane Matthew's destructive visit in 2016 really change the way we live?

Will people clean debris from their ditches the next time the forecast calls for 10 inches of rain? Will they treat heavy rainfall predictions like hurricane forecasts and evacuate low-lying property? Will drivers heed the "turn around, don't drown" warnings?

Will homeowners outside of flood zones buy flood insurance to protect their investment? Will communities give flood potential more consideration as they update building codes and zoning plans? Will builders design new homes and new developments to better handle floods?

Specific steps like those are important, but the Consortium's Fly thinks truly building resilience depends in part on changing attitudes.

"Disasters such as these are emotional events for people, and often cause those affected to want to build back to the way things were," Fly says. "What's important post-event is to act on the emotion and the motivation people have to not only build back, but build back smarter so that maybe next time we can reduce the damage and the suffering."

Flood insurance: Because "we *all* live in a flood plain"

A couple of important and related lessons must be continually re-learned after each major flood.

Although mortgage companies only require flood insurance for those living in the flood zone designated by the Federal Emergency Management Agency (FEMA), it also is a good investment for those outside the flood zone. For instance, in the North Charleston area, 40 percent of homeowners who filed FEMA quick claims for damage after the October 2015 floods lived outside the flood zone, and almost none of them had flood insurance.

Federal assistance is available for those without flood insurance, but it is designed simply to get residents back on their feet. Payments to the 28,163 uninsured households eligible for FEMA assistance in South Carolina in 2015 averaged $3,169, and only about 28 percent of those who applied were deemed eligible.

Russ Dubisky, director of the S.C. Insurance News Service, has been preaching this message for years. Even if your mortgage lender doesn't require flood insurance, it's a good idea if you live anywhere near water.

"We hear it all the time after an event: 'It's never flooded here before,' " Dubisky says. "The reality is, we *all* live in a flood plain."

Despite the relative lack of flooding in South Carolina since 2000, the number of flood insurance policies in the state jumped from 105,000 in 1999 to 199,300 before the 2015 floods, with another 1,200 policies taken out between the October 2015 and October 2016 floods, according to FEMA. The long-term increase can be partially attributed to new construction in flood zones. For example, of 11,340 acres of land converted to development in Charleston County from 1996-2010, nearly 44 percent was in a FEMA-designated flood plain, according to the National Oceanic and Atmospheric Administration's Coastal County Snapshot.

ANOTHER CLEANUP. ***Many residents in North Charleston's Pepperhill subdivision didn't have flood insurance before the October 2015 floods hit them hard. They were required to buy flood insurance to accept federal recovery funds, and they will face less of a financial blow after Hurricane Matthew flooding.***
PHOTO/GRACE BEAHM

Fortunately, many of those new homes have been built with flood resilience in mind in cities and counties that participate in the Community Rating System (CRS), an initiative of FEMA's National Flood Insurance Program. Communities can reduce the cost of flood insurance premiums by 5-to-45 percent for their residents if steps are taken to reduce flood damage. Some of the recommended actions include publicizing which areas are flood-prone, developing updated flood maps, regulating the runoff allowed from new developments, and routinely inspecting culverts and ditches.

Storm surge: "Powerful is an understatement"

Hurricane Matthew hit South Carolina with storm surge, the one variety of flooding the state had avoided in the October 2015 rain event, and that meant new lessons.

The first was that storm surge height is less important than inundation depth. Charleston Harbor registered a storm surge of just over six feet during Matthew, but that peak fortunately arrived close to low tide. The inundation depth—or height of water above local ground level—was one-to-two feet on the low-lying portions of the Charleston peninsula.

On the other hand, Matthew's surge hit closer to high tide on Hilton Head Island, Hunting Island, and Edisto Beach, creating higher inundation levels. At Edisto, the National Weather Service reported a water line about four-feet high on a house across from the beach.

Matthew also offered a reminder of the power of surge, the wall of water created by hurricane winds and low pressure. The force pushed so much sand onto Edisto Beach's Palmetto Boulevard it appeared the beach had moved a block or two inland.

Storm surge estimated at around nine feet took its toll on Hunting Island State Park. "The surge is real, and too often we don't really see its impact," says Phil Gaines, director of S.C. State Parks. "We focus on the dramatic visuals of twisted and downed trees."

MIGHTY FORCE. *Sand flushed nearly two blocks inland at Edisto Beach indicates the power of Hurricane Matthew's storm surge.*
PHOTO/S.C. DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL

Powerful moving water rushed over dunes and through Hunting Island's oceanfront campground, tearing the door off a bathroom and depositing sand so deep it nearly covered the toilet seats.

"Powerful is an understatement," Gaines says. "Evacuation of staff and visitors is imperative."

The park staff knew what to do from past hurricanes, but Matthew impressed the message on a new generation. Park employees left ahead of the storm, and they had equipment secure and ready to get back once the water began to subside, Gaines says. Three weeks after Matthew, all of the parks—with the exception of Hunting Island and the oceanfront campground at Edisto Beach—were open again.

Reading and Websites

Carolinas Integrated Sciences and Assessments: *The South Carolina Floods of October 2015.*
www.cisa.sc.edu

Charleston Resilience Network: *Understanding the October 2015 Charleston Floods: A Symposium Report.*
www.charlestonresilience.net/flood-symposium

City of Charleston *Sea-Level Rise Strategy.*
www.charleston-sc.gov/DocumentCenter/View/10089

FEMA National Flood Insurance Program Community Rating System.
www.fema.gov/national-flood-insurance-program-community-rating-system

NOAA National Water Model.
www.water.noaa.gov/about/nwm

NOAA Service Assessment: *The Historic South Carolina Floods of October 1-5, 2015.*
www.nws.noaa.gov/os/assessments/pdfs/SCFlooding_072216_Signed_Final.pdf

S.C. Coastal Water Monitoring Network Data Portal.
www.scseagrant.org

S.C. Department of Commerce: *State of South Carolina: Action Plan for Disaster Recovery.*
http://sccommerce.com/sites/default/files/all/forpostingsouth_carolina_action_plan_1600623_publiccomment.pdf

S.C. Emergency Management Division: *Hazard Mitigation Plan.*
http://scemd.org/files/Mitigation/State_Hazard_Mitigation_Plan/1_SHMP_FINAL_2013.pdf

S.C. Sea Grant Consortium: "Compilation of Lessons Learned," Vol. 29, No. 4, Fall 2016 issue of *Coastal Heritage.*
www.scseagrant.org/Content/?cid=917

NEWS & NOTES

Consortium receives $1.33 million for Sea Grant activities

The National Sea Grant College Program awarded $1.33 million to the S.C. Sea Grant Consortium to support the first year of its research, extension, communications, and education efforts for 2016-2018. As part of this award, the following eight peer-reviewed research projects were selected for funding. More details are posted on the Consortium's website at www.scseagrant.org/Research.

COASTAL AND OCEAN LANDSCAPE

- *How does coastal development impact groundwater inputs to estuarine tidal creeks?* Alicia Wilson and Erik Smith, University of South Carolina. Researchers will assess the impact of coastal development on nutrients that move into tidal creeks underground at various development sites. The study will measure variations in the concentration of nutrients in groundwater with a goal of building models to better describe the impact of development sites on the nutrient level in tidal creeks.

SUSTAINABLE COASTAL DEVELOPMENT AND ECONOMY

- *Sources and impacts of microplastic contamination in Charleston Harbor and Winyah Bay*. Peter Van den Hurk and Charles Rice, Clemson University, and John Weinstein, The Citadel. Previous studies have found high concentrations of microplastics in estuarine invertebrates such as grass shrimp in Charleston Harbor, and lower concentrations in Winyah Bay near Georgetown. This study will build on that work by focusing on sources of black plastic fragment debris and its toxicity in grass shrimp, copepods, and mummichogs.
- *Safeguarding environmental and public health by developing a tool to rapidly detect cyanobacteria that can cause harmful algal blooms (HABs)*. Dianne Greenfield, University of South Carolina and S.C. Department of Natural Resources, and William Jones, University of South Carolina. Researchers will develop a genetic tool and assess its effectiveness in early and cost-effective detection of a toxin associated with HABs.
- *Determining potential sedimentation rates in stormwater ponds to help assess future dredging costs*. Erik Smith and Claudia Benitez-Nelson, University of South Carolina. Researchers will determine sediment accumulation rates in a variety of stormwater ponds in coastal South Carolina. That data will help better predict the need for future dredging and will measure nutrient concentrations in pond sediments to help better understand the role of ponds in nutrient sequestration.

SUSTAINABLE FISHERIES AND AQUACULTURE

- *Determining the optimal balance of stock enhancement and harvest reduction to restore inshore cobia population in South Carolina*. Tanya Darden, S.C. Department of Natural Resources. The genetically distinct inshore population of cobia in South Carolina waters has declined to the point conservation action might be necessary. Researchers will develop a model of cobia genetics and population variables to help forecast outcomes of various levels of management.
- *Genetic diversity in historic overfished populations and contemporary recovered populations of black sea bass*. Tanya Darden, S.C. Department of Natural Resources. Researchers will use a collection of bones from black sea bass to determine changes through time in the genetic diversity of the population. Genetic samples from bones from known periods of over-fishing and recovery can determine how population size impacts genetic diversity. The data will help managers understand the population's ability to recover and its adaptability to environmental change.

HAZARD RESILIENCE IN COASTAL COMMUNITIES

- *Adaptability toolkit for South Carolina's coastal water infrastructures*. Kalyan Piratla, Clemson University. The project is a collaboration among research scientists, water infrastructure agencies, and consumer groups to predict the future impacts of climate change on water infrastructures. Science-based analysis of potential challenges and costs of adaptation strategies will aid in planning for climate resilience.
- *Designing low-impact development (LID) technologies to better respond to intense rainfall events*. Nigel Kay and William Martin, Clemson University. Researchers will develop models to help quantify the hydraulic and hydrologic capacity of LID technology, including green roofs and porous pavement. Models developed will predict the impact of LID technologies at various volumes of rainfall.

NEWS & NOTES

Consortium teaches climate change concepts to educators

Educators from throughout the country explored strategies for incorporating climate change into educational activities during a two-day workshop at the South Carolina Aquarium in August.

E.V. Bell, the S.C. Sea Grant Consortium's marine education specialist, and Elizabeth Fly, the Consortium's coastal climate extension specialist, received funding from the National Oceanic and Atmospheric Administration (NOAA) Climate Stewards Program to host the "Rising Tides and Changing Times" workshop.

Educators from throughout the country gathered at the South Carolina Aquarium to explore incorporating climate change into educational activities.
PHOTO/SUSAN FERRIS HILL/S.C. SEA GRANT CONSORTIUM

Formal and informal educators from South Carolina, North Carolina, Georgia, New Jersey, Pennsylvania, Massachusetts, Washington, D.C., and U.S. Virgin Islands attended. Partners in the effort included the Consortium, the Aquarium, NOAA, and the National Park Service.

Educators discussed the past, present, and future of Fort Sumter during a trip to the national monument in Charleston Harbor. They scurried through Charleston on an "Amazing Race"-style scavenger hunt that showcased the challenges associated with sea-level rise. And they learned from Aquarium staff members about the impacts of climate change on marine wildlife.

Each activity included connections to lesson plans and other resources to pass along the knowledge to students. Educators who didn't attend the workshop can find educational tools focused on climate change at www.climate.gov/teaching.

Flood information gap prompts water monitoring data portal

While scenes of flooded neighborhoods, failed dams, and washed out roads in South Carolina made headlines nationwide in October 2015, the deluge also impacted water quality.

In the aftermath of the event, the S.C. Sea Grant Consortium recognized the need for a readily accessible, common platform to illustrate and share information on hydrological and water-quality monitoring site locations. The Consortium then contacted a number of state and federal agencies and academic institutions that conduct long-term and event-based monitoring programs.

"Together with these partners, the Consortium is developing a web-based visualization tool—the S.C. Coastal Water Monitoring Network," said Rick DeVoe, Consortium executive director. "When completed, this tool will allow scientists, resource managers, policy-makers, and citizens to easily identify water resource monitoring locations. They can gather information on who is conducting the monitoring, the parameters being monitored and measured, and click on a link to the website where detailed data and information for each location can be accessed."

Partners in the effort to date include Coastal Carolina University; College of Charleston; S.C. Department of Natural Resources; S.C. Department of Health and Environmental Control; University of South Carolina; U.S. Forest Service; U.S. Geological Survey; North Inlet-Winyah Bay National Estuarine Research Reserve; and Charleston Waterkeeper.

The visualization tool is designed to serve as a time-saving first step for water-resource managers and researchers, whether anticipating future events or examining archived data on historical events, such as Hurricane Hugo or the 2015 and 2016 flooding. It provides a baseline for understanding the status of water resources and context for the impacts of climate and weather events.

The tool is accessible from the Consortium's homepage at www.scseagrant.org.

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EBBS & FLOWS

American Meteorological Society Meeting

Seattle, Washington
January 22-26, 2017

More than 3,000 scientists, educators, students, and other professionals gather to learn about the latest in climate, weather, and water. The 2017 meeting theme is "Observations Lead the Way," and sessions will focus on the priority of obtaining accurate observations and information. Visit https://annual.ametsoc.org/2017 for more information.

Coastal GeoTools

North Charleston, South Carolina
February 6-9, 2017

This conference brings together watershed scientists, stakeholders, and managers to share scientific advances and management strategies to sustain the country's water resources. The agenda focuses on geospatial data, tools, technology, and information for coastal resource management professionals. For more information, visit http://coastalgeotools.org.

Aquatic Sciences Meeting

Honolulu, Hawaii
February 26-March 3, 2017

Ocean scientists, engineers, educators, students, and policy-makers come together to address marine-science issues. Sponsored by the Association for the Sciences of Limnology and Oceanography, the 2017 meeting will embrace the host state's cultural perspective linking land, water, and people. Visit http://aslo.org/meetings/index.html for more information.

Subscriptions are free upon request by contacting: Joey.Holleman@scseagrant.org

ATTENTION SCHOOL TEACHERS! The S.C. Sea Grant Consortium has designed supplemental classroom resources for this and past issues of *Coastal Heritage* magazine. *Coastal Heritage Curriculum Connection*, written for K-12 educators and their students, is aligned with the South Carolina state standards for the appropriate grade levels. Includes standards-based inquiry questions to lead students through explorations of the topic discussed. *Curriculum Connection* is available online at www.scseagrant.org/education.

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